AEC Category: HEALTH AND SAFETY

CEX-62.80b

CIVIL EFFECTS STUDY

SMALL BOY PROJECT 62.80b
AERORADIOACTIVITY SURVEY

Edgerton, Germeshausen & Grier, Inc.

Issuance Date: May 1967

CIVIL EFFECTS TEST OPERATIONS
U.S. ATOMIC ENERGY COMMISSION

Printed in USA. Price $3.00. Available from the Clearinghouse for Federal Scientific and Technical Information, National Bureau of Standards, U. S. Department of Commerce, Springfield, Virginia 22151.

USAEC Division of Technical Information Extension, Oak Ridge, Tennessee

SMALL BOY PROJECT 62.80b
AERORADIOACTIVITY SURVEY

By

Edgerton, Germeshausen & Grier, Inc.

Edgerton, Germeshausen & Grier, Inc.
Santa Barbara, California
November 1965

NOTICE

This report is published in the interest of providing information which may prove of value to the reader in his study of effects data derived principally from nuclear weapons tests and from experiments designed to duplicate various characteristics of nuclear weapons.

This document is based on information available at the time of preparation which may have subsequently been expanded and re-evaluated. Also, in preparing this report for publication, some classified material may have been removed. Users are cautioned to avoid interpretations and conclusions based on unknown or incomplete data.

ABSTRACT

Aerial radiometric surveys during the Small Boy operation were conducted by the U. S. Geological Survey (ARMS-I) and by Edgerton, Germeshausen & Grier, Inc. (ARMS-II). The preshot gamma background to a distance of 300 miles from ground zero was determined on four arcs. Postshot operations were started on July 16, 1962 (D + 2 days), and were completed on July 19, 1962. The conterminous fallout pattern was surveyed from 15 to 125 miles from ground zero, and a large area of fallout south and east of Provo, Utah, was located and surveyed. The aerial survey data for these two areas are presented in the form of H + 24-hr ground-dose-rate contour maps, the outermost contour being 0.2 mr/hr. Reconnaissance flights north and east of the Utah area provided additional information on the deposition of Small Boy debris. A detailed aerial survey made in East Indian Springs Valley illustrates the heterogeneity of fallout deposition. The major problems involved in the utilization of aerial gamma counting-rate data are discussed, i.e., those of correcting for radioactive decay and of converting to dose rate.

CONTENTS

ILLUSTRATIONS

SMALL BOY PROJECT 62.80b AERORADIOACTIVITY SURVEY

1 INTRODUCTION

1.1 Objectives

The primary objective of the Civil Effects Test Operations (CETO) Project 62.80b, Aerial Radiometric Surveys, was to determine the aerial distribution of fallout deposited on the ground by Small Boy shot. Information obtained by aerial surveys in the area from 10 to 200 miles from ground zero was to be used by other CETO projects in determining the places where plant, animal, and soil specimens were to be collected.

Secondary objectives, if time and the nature of the fallout pattern permitted, were to obtain data to improve the correlation between ARMS-I and ARMS-II and to study (1) the decay in gamma counting rate at 500 ft (aerial gamma decay) in contrast to the decay in dose rate from ground debris as a function of time and distance from ground zero, (2) the conversion of counting rate at 500 ft to dose rate at 3 ft as a function of time and distance from ground zero, and (3) the attenuation with altitude of gamma rays from fallout as a function of time and distance from ground zero.

1.2 Development of ARMS

Experimental aerial measurements of terrestrial radioactivity were conducted in the United States as early as 1948 to establish the feasibility of aerial prospecting for uranium ore. Studies of the U. S. Geological Survey (USGS) and of the Oak Ridge National Laboratory (ORNL) led to the development of instrumentation and techniques[1] that were used in June 1950 to make the first systematic aerial survey of a large area (1600 sq miles) of the United States. The Environmental Radiation Division (EnRad) of the University of California at Los Angeles (UCLA) and CETO tested the equipment and techniques of the USGS–ORNL system (ARMS-I) during the fall environmental survey, 1956, and included the mapping of the residual hot-line of radioactive debris from Met shot, Operation Teapot. This system and technique were used by UCLA routinely to determine fallout patterns during Operations Plumbbob (1957) and Hardtack II (1958). A revised aerial survey system, ARMS-II,[2,3] was developed in 1960 for CETO by EG&G. ARMS-I and ARMS-II were used in conjunction with EnRad studies of the fallout pattern from Danny Boy shot in March 1962. Both systems took part in Sedan Project 62.80b, Aerial Radiometric Surveys, in June and July 1962.

1.3 Background Radiation

The gamma-ray activity that is measured by ARMS scintillation detection equipment at 500 ft above the ground has two principal sources: (1) terrestrial and (2) nonterrestrial. The nonterrestrial sources include cosmic radiation, radionuclides in the atmosphere, and extraneous sources, such as aircraft contamination and ^{137}Cs calibration sources in the aircraft. The relative contribution of each source at a particular time cannot be measured directly dur-

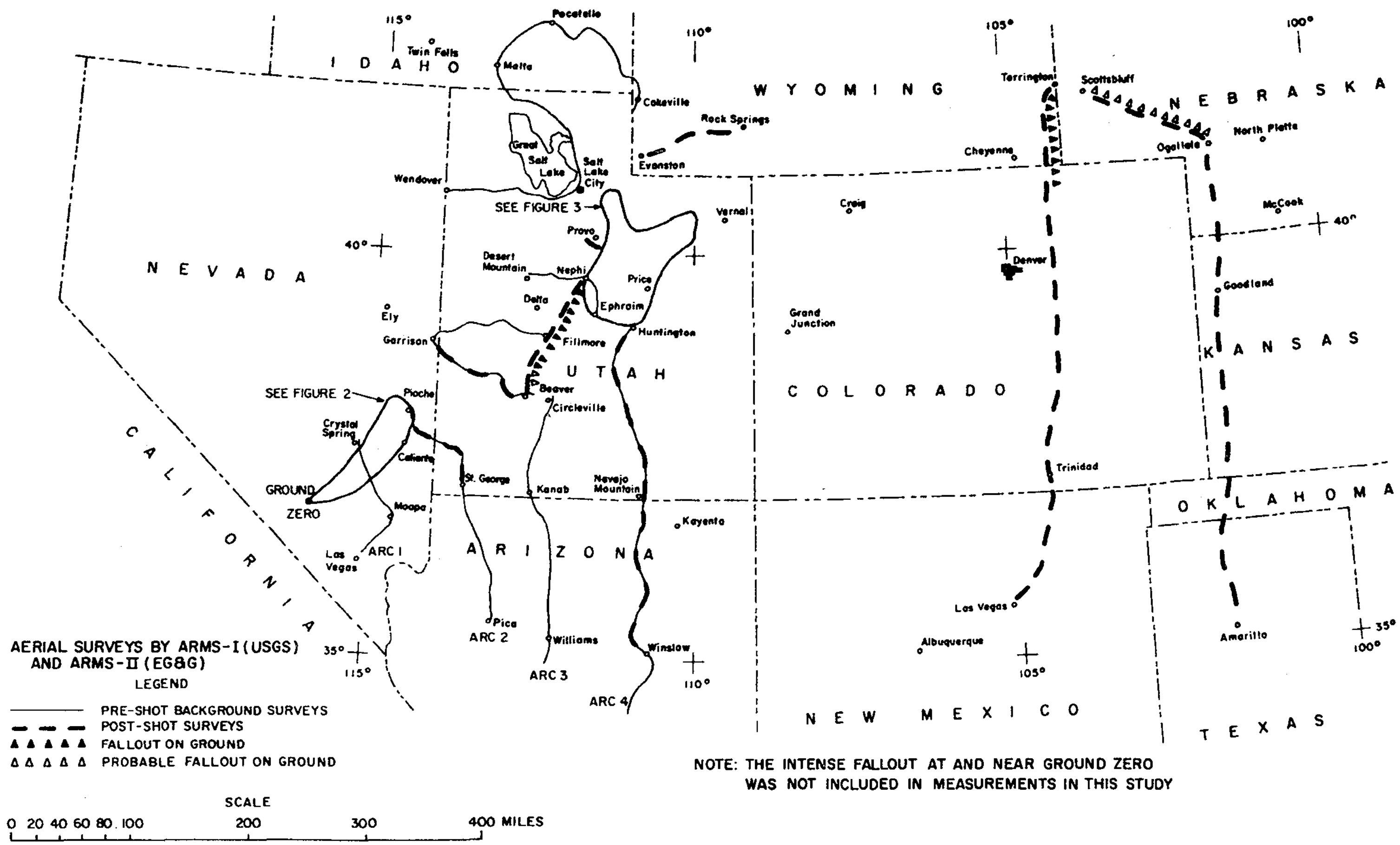

Fig. 1—Index map of Small Boy Project 62.80b Aerial Radiometric Surveys.

ing the survey, but certain assumptions and calibration procedures permit reliable estimates to be made.

The counting rate at 2000 to 3000 ft aboveground, where negligible radiation from the ground is present, is considered to be due to the nonterrestrial radiation. The cosmic-radiation component at 500 ft above the ground is due mainly to the air-scattered gamma rays that are induced by cosmic particles. The natural radionuclides in the atmosphere are assumed to be uniformly distributed, and their contribution to the nonterrestrial component is normally small. Since surveys of a fallout pattern from a nuclear detonation are not made until D + 1 day or later, most of the fallout has deposited on the ground or has moved out of the area. If any fission products remain in the air, they are assumed to be uniformly distributed. The nonterrestrial counting rate, measured each day before, during, and after the ARMS flights, was subtracted from the gross count at 500 ft above the ground to give the recorded net terrestrial gamma counting rate.

The terrestrial component of the gamma radiation found at 500 ft above the ground comes from the radionuclides in the surficial few inches of earth materials. Members of the uranium and thorium series and ^{40}K in soil and, to a lesser extent, in rock are the major natural sources of gamma rays. Measurement of the preshot background makes it possible to determine the counting rate due to debris deposited after a particular event.

1.4 Air–Ground Dose-rate Conversion Factors

Data for the conversion of counting rate at 500 ft over the entire area of fallout pattern to dose rate at 3 ft are not adequate for all situations. This problem is complicated by (1) the variable response of field dose rate meters used to measure 3-ft dose rates, (2) the necessity for detailed dose-rate and counting-rate measurements in all parts of the fallout pattern, (3) the energy dependence of the detectors, and (4) the variable terrain features. During Operation Plumbbob (1957) it was found that a counting rate of approximately 77,000 counts/sec measured 500 ft above the ground by ARMS-I equipment was equivalent to 1 mr/hr measured 3 ft above the ground with a Radiac model AN/PDR-T1B.[5,6] In this study it was found that the response of various dose-rate survey meters varied by at least a factor of 2.

The ARMS-II instrumentation was designed to give counting-rate data comparable to the data of existing ARMS-I equipment. Both units were flown over the Extended Source Calibration Area (ESCA) at the Nevada Test Site in 1960, and the results of the test have been published.[7] Over ^{137}Cs sources producing a 3-ft ground dose rate of about 0.2 mr/hr, the counting-rate to dose-rate conversion factor was about 25,000 counts/sec at 500 ft equals 1 mr/hr at 3 ft.

Owing to insufficient information, an approximate average value of the two conversion factors given previously was selected for use in this study. Thus 50,000 counts/sec at 500 ft was taken to indicate 1 mr/hr at 3 ft.

Additional data from fallout of different ages and patterns and over a variety of types of terrain are needed to properly evaluate the counting-rate to dose-rate conversion.

2 OPERATIONS

2.1 Preshot

Preshot activities of the CETO 62.80b Aerial Radiometric Surveys consisted in determining the representative preshot background gamma radioactivity in the area east and north of ground zero (Fig. 1). The following arcs approximately 60, 130, 180, and 300 miles from ground zero were flown by ARMS-I and ARMS-II: arc 1, Nellis Air Force Base, Moapa, and Crystal Spring; arc 2, Pica, St. George, Crestline, and Pioche; arc 3, south of Williams, Kanab, Circleville, Beaver, Garrison, and Fillmore; and arc 4, south of Winslow, Navajo Mountain, Huntington–Ephraim, Nephi, and Desert Mountain. The Small Boy event was modified in early July to include firing with a south wind. Accordingly, ARMS-I flew a background line (Wendover, Salt Lake City, Malta, Pocatello, and Cokesville) on July 10 to determine the post-Sedan background in the area between the Sedan fallout pattern and the original Small Boy arcs.

2.2 Postshot

Postshot operations on Small Boy were started on D + 2 days (July 16). The aerial surveys were delayed from D + 1 day to D + 2 days to permit fine-grained debris to settle to the ground, thereby minimizing the probability of contamination of the ARMS aircraft. Since early information from ground monitors indicated that the Small Boy pattern was small, it was decided to survey the pattern with one aircraft. On D + 2 days ARMS-II surveyed the fallout pattern from Indian Springs Valley to Caliente (Fig. 2). Surveying was completed by ARMS-II on D + 3 days (July 17). The dashed lines of Fig. 2 show the estimated locations of the radiation isopleths.

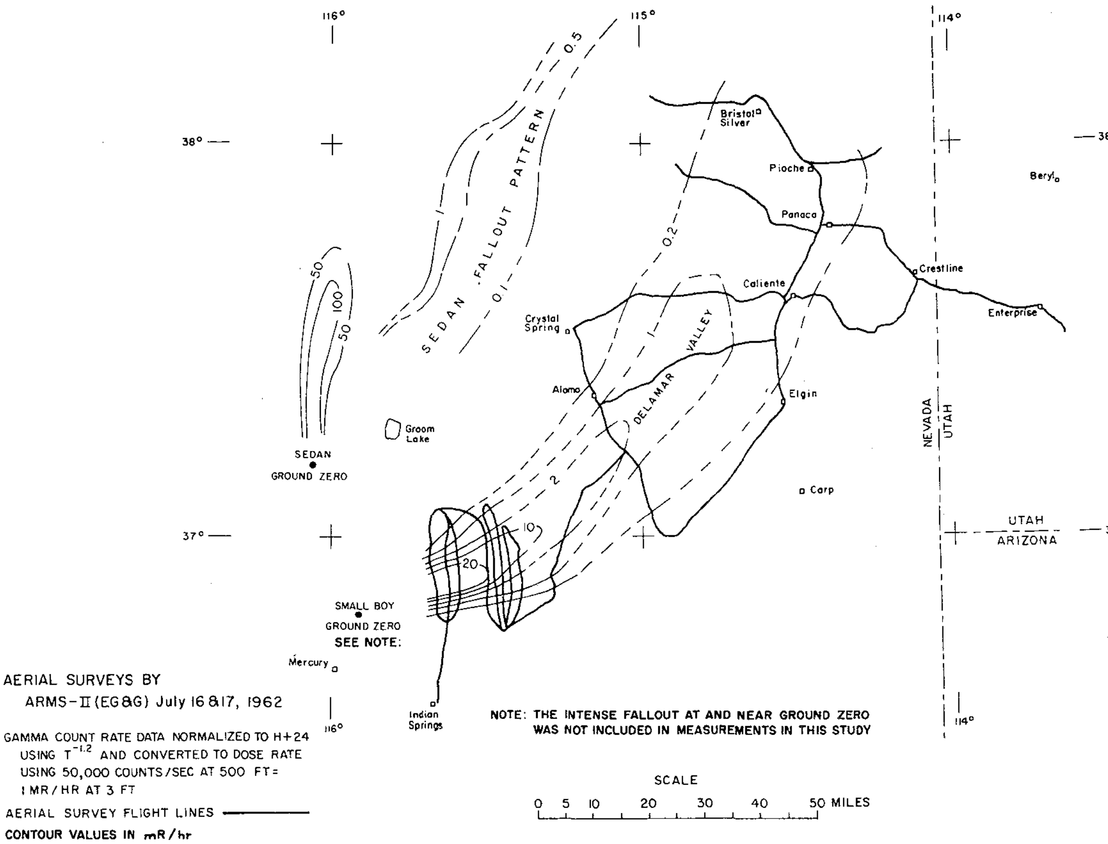

Fig. 2—Fallout pattern of Small Boy.

An analysis of the Small Boy meteorological data by J. J. Fuquay, Hanford Atomic Products Operation, Richland, Wash., and a conference with Fuquay and K. H. Larson, Laboratory of Nuclear Medicine and Radiation Biology, UCLA, indicated that the top of the Small Boy cloud, which had been sheared to the east, might produce a "hotspot" along the easternmost background line, arc 4. Since ARMS-I was not needed for the close-in pattern, it was given the mission of surveying arc 4 (Fig. 1) on D + 2 days. Anomalous radioactivity was detected a few miles south of Huntington. A hotspot covering about 5000 sq miles east and south of Provo was outlined (Fig. 3). ARMS-II did some additional surveying in the hotspot on D + 3 days and on D + 4 days flew north of the Uinta Mountains on U. S. Highway 30 from Evanston to Rock Springs. On D + 4 days (July 18) ARMS-I left Las Vegas, Nev., for Washington, D. C., and surveyed a line east of the Rocky Mountains from Las Vegas, N. Mex., to Torrington, Wyo. (Fig. 1). Anomalous activity was detected east of Cheyenne, Wyo. On D + 5 days (July 19), ARMS-I surveyed in the North Platte River Valley east of Scottsbluff, Nebr., where possibly anomalous activity was detected, and from Ogallala, Nebr., to Amarillo, Tex.

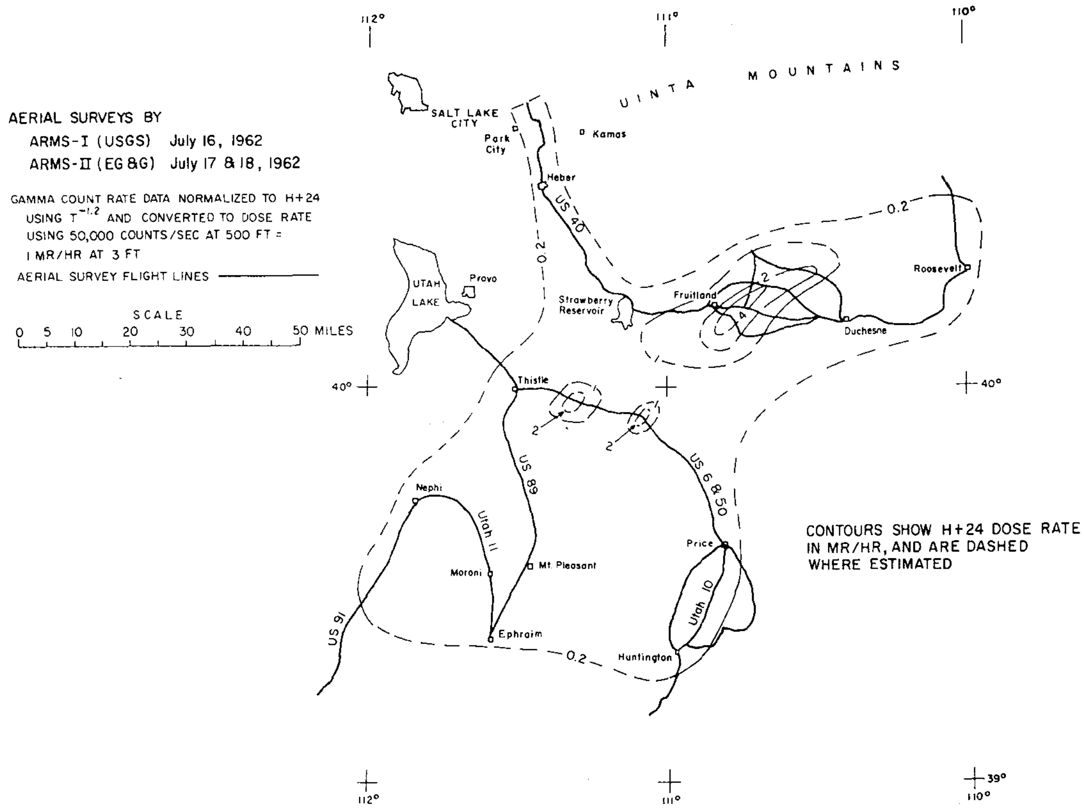

Fig. 3—Fallout pattern in Fruitland area.

3 INSTRUMENTATION

The ARMS-I and ARMS-II systems use thallium-activated sodium iodide crystals and photomultiplier tubes to detect gamma radiation. Different electronic techniques are used to handle the pulses from the photomultipliers, but the counting rates of the two systems are comparable. Details of the systems are described in the literature.[1-3]

The ARMS-I and ARMS-II gamma-radiation detectors are calibrated with ^{137}Cs, in accordance with the method described by Davis and Reinhardt.[1] The two techniques differ in minor details, but they are generally similar. Very briefly, the procedure consists in positioning a small ^{137}Cs source adjacent to the crystals, setting the energy discriminator at 662 kev, and adjusting the gain to obtain a predetermined counting rate. This calibration procedure on both aircraft requires less than 1 min and is performed periodically during survey operations.

4 AERORADIOACTIVITY DATA

The raw counting-rate data recorded in the air by ARMS-I on graphic milliammeters and by ARMS-II on decimal tape were plotted on maps. The counting-rate data were then corrected for decay, converted to dose rate, and contoured.

4.1 ARMS-I Data Recording and Reporting

The ARMS-I aeroradioactivity data were recorded as continuous profiles on strip-chart recorders. In view of the requirement for early use of the data, however, the ARMS-I counting rate was also periodically entered on the observer's copy of the flight map (1 : 250,000 scale) as the survey progressed. Upon completion of the flight, the continuous profiles were used in

editing and adding detail to the map prepared in the air. This map, which showed the radiation intensities along the flight path of the aircraft, was available shortly after completion of each flight.

4.2 ARMS-II Data Recording and Reporting

The ARMS-II aeroradioactivity data and the locations of data points were recorded on decimal tape. The major features of the fallout pattern were noted on the flight map to provide in-flight characterization of the pattern for more efficient surveying and to make information on the location of the fallout available as soon as the flight was completed, as in the ARMS-I operation. Upon completion of each flight, the decimal tape was edited, and the significant data points were plotted on tracing paper at a scale of 1 : 250,000. The data were then graphically corrected for minor "Doppler error" and compiled on a 1 : 250,000-scale map. This map, which showed counting rate, had data points plotted with an accuracy of 0.05 in. and was normally completed less than 8 hr after each flight.

4.3 Data Reduction

The first step in reducing the ARMS data was to correct the counting rate for radioactive decay. Sufficient data were available to allow estimating to within about 15 min of the time a particular area was surveyed. The data were corrected for decay to H + 24 hr with the factor $t^{-1.2}$.

After correction for decay, the data were converted from counting rate at 500 ft above the ground to dose rate at 3 ft.

The H + 24-hr dose-rate data, at a scale of 1 : 250,000, were contoured with 20, 10, 4, 2, and 0.2 mr/hr contour lines. The contour map of the fallout pattern was then reduced in scale from 1 : 250,000 (1 in. equals 4 miles) to 1 : 1,000,000 (1 in. equals 16 miles).

The detailed ARMS-II data from East Indian Springs Valley (Fig. 4) were plotted at a scale of 1 : 62,500 (approximately 1 in. equals 1 mile). The low-sensitivity detector was used for most of this survey, but the data are reported as large-crystal-equivalent counting rates. The data were not corrected for decay before contouring because the elapsed time for the survey was about 1 hr. Locations of ground dose-rate measurements are indicated by the circled letters, A and B, in Fig. 4.

5 RESULTS

The pre-Small Boy background aeroradioactivity east of the Nevada Test Site was determined in a 100° arc to a distance of 300 miles from ground zero. The gamma counting rate at 500 ft above the ground ranged from 300 to 1500 counts/sec except in the vicinity of several uranium mines where a rate of as much as 3000 counts/sec was recorded.

The post-Small Boy surveys mapped the fallout pattern from 15 to 120 miles from ground zero, outlined a hotspot covering 5000 sq miles south and east of Provo, Utah, and located additional anomalous radioactivity east of Cheyenne, Wyo.

The Small Boy fallout pattern was surveyed from Indian Springs Valley to Pioche and Bristol Silver (Fig. 2). The "hot line," or line of maximum intensity, trends in an arc from about N. 70° E. in Indian Springs Valley to about N. 30° E. near Caliente. The fallout pattern is slightly asymmetric, with the hot line north of the center line. In contrast to the Sedan pattern, where there was a "feathering out," or gradual reduction, in the amount of fallout on the east,[4] the area of Small Boy fallout that was detected from the air was fairly definite. It did not extend beyond the 0.2 mr/hr line more than five miles in the western part of the pattern and 10 miles in the vicinity of Caliente and Pioche.

A detailed survey that consisted of five flight lines was flown in East Indian Springs Valley on D + 3 days. The contoured large-crystal-equivalent gamma-counting-rate data in thousands of counts per second at 500 ft above the ground are shown in Fig. 4. A correction for decay was not made because the elapsed time for the survey was only about 1 hr. The

data exhibit an internal consistency and interesting heterogeneity in the amounts of gamma radiation coming from the ground. In the west part of the area, the hot line is south of the center of the fallout pattern, and in the east it is north of the center. A pronounced area of lower intensity occurs in the center of the valley between the areas of higher intensity on the west and on the east.

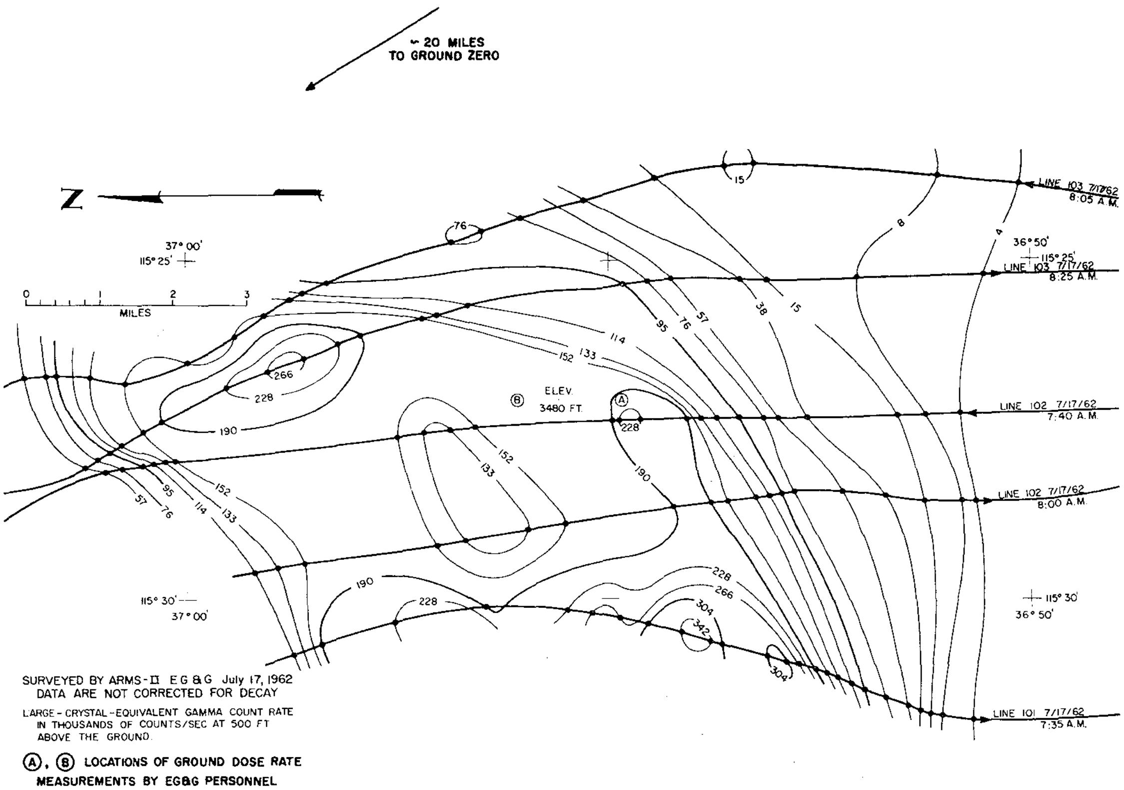

Fig. 4—Aeroradioactivity map of Small Boy fallout in East Indian Springs Valley.

A general hotspot east and south of Provo was located and surveyed by ARMS-I on D + 2 days (Figs. 1 and 3). Gamma counting rates clearly above background were detected about 25 miles south of Huntington. Except for two small areas of moderate counting rate, generally low levels were recorded between Huntington and Provo. After takeoff from Provo it was determined that the ARMS-I aircraft background had increased about 1500 counts/sec because of contamination. This counting rate was subtracted from the data recorded after passing Price. Low levels were recorded southeast of Salt Lake City along U. S. Highway 40 to Strawberry Reservoir, and an area of moderate radioactivity was found between Strawberry Reservoir and Duchesne. In the area south of Provo, detectable fallout was found along U. S. Highway 91 to about 90 miles south of Nephi, and fallout was probably present as far as Beaver.

On D + 3 and D + 4 days, ARMS-II accomplished a detailed survey of the moderately radioactive area near Fruitland and the area between Huntington and Price and ascertained that the hotspot did not extend north of the Uinta Mountains in the vicinity of Rock Springs.

To determine whether or not fallout was present east of the Rocky Mountains, ARMS-I flew a line from Las Vegas, N. Mex., to Torrington, Wyo., on July 18, D + 4 days (Fig. 1). Anomalous radioactivity was found on the north end of the line from southeast of Cheyenne to a few miles south of Torrington. Gamma counting rates were clearly above background for a distance of about 80 miles, with maximum readings of 4800 and 4200 counts/sec.

On the following day, July 19, ARMS-I detected possibly anomalous radioactivity in the North Platte River Valley. Although the counting rates were above normal, they were less than

CIVIL EFFECTS TEST OPERATIONS REPORT SERIES (CEX)

Through its Division of Biology and Medicine and Civil Effects Test Operations, the Atomic Energy Commission conducts certain technical tests, exercises, surveys, and research directed primarily toward practical applications of nuclear effects information and toward encouraging better technical, professional, and public understanding and utilization of the vast body of facts useful in the design of countermeasures against weapons effects. The activities carried out in these studies do not require nuclear detonations.

The following is a partial list of reports available from studies that have been completed. All reports listed are available, at $3.00 each, from the Clearinghouse for Federal Scientific and Technical Information, U. S. Department of Commerce, Springfield, Va. 22151.

CEX-58.1, Experimental Evaluation of the Radiation Protection Afforded by Residential Structures Against Distributed Sources, J. A. Auxier, J. O. Buchanan, C. Eisenhauer, and H. E. Menker, 1959.
CEX-58.7, AEC Group Shelter, AEC Facilities Division, Holmes & Narver, Inc., 1960.
CEX-58.8, Comparative Nuclear Effects of Biomedical Interest, C. S. White, I. G. Bowen, D. R. Richmond, and R. L. Corsbie, 1961.
CEX-58.9, A Model Designed to Predict the Motion of Objects Translated by Classical Blast Waves, I. G. Bowen, R. W. Albright, E. R. Fletcher, and C. S. White, 1961.
CEX-59.1, An Experimental Evaluation of the Radiation Protection Afforded by a Large Modern Concrete Office Building, J. F. Batter, Jr., A. L. Kaplan, and E. T. Clarke, 1960.
CEX-59.7B (Pt. I), Experimental Radiation Measurements in Conventional Structures. Part I. Radiation Measurements in Two Two-story and Three One-story Typical Residential Structures Before and After Modification, Z. G. Burson, 1966.
CEX-59.7B (Pt. II), Experimental Radiation Measurements in Conventional Structures. Part II. Comparison of Measurements in Above-ground and Below-ground Structures from Simulated and Actual Fallout Radiation, Z. G. Burson, 1964.
CEX-59.7B (Pt. III), Experimental Radiation Measurements in Conventional Structures. Part III. The Attenuation of Air-scattered Radiation in a Basement, Z. G. Burson, 1965.
CEX-59.13, Experimental Evaluation of the Radiation Protection Afforded by Typical Oak Ridge Homes Against Distributed Sources, T. D. Strickler and J. A. Auxier, 1960.
CEX-59.14, Determinations of Aerodynamic-drag Parameters of Small Irregular Objects by Means of Drop Tests, E. P. Fletcher, R. W. Albright, V. C. Goldizen, and I. G. Bowen, 1961.
CEX-60.1, Evaluation of the Fallout Protection Afforded by Brookhaven National Laboratory Medical Research Center, H. Borella, Z. Burson, and J. Jacovitch, 1961.
CEX-60.3, Extended- and Point-source Radiometric Program, F. J. Davis and P. W. Reinhardt, 1962.
CEX-60.5, Experimental Evaluation of the Fallout-radiation Protection Afforded by a Southwestern Residence, Z. Burson, D. Parry, and H. Borella, 1962.
CEX-60.6, Experimental Evaluation of the Radiation Protection Provided by an Earth-covered Shelter, Z. Burson and H. Borella, 1962.
CEX-61.1 (Prelim.), Gamma Radiation at the Air-Ground Interface, K. O'Brien and J. E. McLaughlin, Jr., 1963.
CEX-61.4, Experimental Evaluation of the Fallout-radiation Protection Provided by Selected Structures in the Los Angeles Area, Z. G. Burson, 1963.
CEX-62.01, Technical Concept—Operation BREN, J. A. Auxier, F. W. Sanders, F. F. Haywood, J. H. Thorngate, and J. S. Cheka, 1962.
CEX-62.2, Nuclear Bomb Effects Computer (Including Slide-rule Design and Curve Fits for Weapons Effects), E. R. Fletcher, R. W. Albright, R. F. D. Perret, Mary E. Franklin, I. G. Bowen, and C. S. White, 1963.
CEX-62.11, Distribution of Weapons Radiation in Japanese Residential Structures, J. S. Cheka, F. W. Sanders, T. D. Jones, and W. H. Shinpaugh, 1965.
CEX-62.12, Energy and Angular Distribution of Neutrons and Gamma Rays—Operation BREN, J. H. Thorngate, J. A. Auxier, F. F. Haywood, and S. Helf, 1967.
CEX-62.13, Post Pulse Gamma-radiation Spectrum—Operation BREN, J. H. Thorngate and E. T. Loy, 1966.
CEX-62.14, An Experimental Investigation of the Spatial Distribution of Dose in an Air-over-Ground Geometry, F. F. Haywood, J. A. Auxier, and E. T. Loy, 1964.
CEX-62.50, Neutron-field and Induced-activity Measurements—Operation BREN, F. M. Tomnovec and J. M. Ferguson, 1965.
CEX-62.81 (Final), Ground Roughness Effects on the Energy and Angular Distribution of Gamma Radiation from Fallout, C. M. Huddleston, Z. G. Burson, R. M. Kinkaid, and Q. G. Klinger, 1964.
CEX-63.3, Barrier Attenuation of Air-scattered Gamma Radiation, Z. G. Burson and R. L. Summers, 1965.
CEX-63.7, A Comparative Analysis of Some of the Immediate Environmental Effects at Hiroshima and Nagasaki, C. S. White, I. G. Bowen, and D. R. Richmond, 1964.
CEX-63.10, Design of a Shielded Source for the Irradiation of Natural Animal Populations, A. C. Lucas, Z. G. Burson, and R. E. Lagerquist, 1966.
CEX-64.3, Ichiban: The Dosimetry Program for Nuclear Bomb Survivors of Hiroshima and Nagasaki—A Status Report as of April 1, 1964, J. A. Auxier, 1964.
CEX-64.7, Neutron and Gamma-ray Leakage from the Ichiban Critical Assembly, J. H. Thorngate, D. R. Johnson, and P. T. Perdue, 1966.
CEX-65.01, Feasibility Study: Intense 14-Mev Neutron Source for Operation HENRE, T. G. Provenzano, E. J. Story, F. F. Haywood, and H. T. Miller, 1966.
CEX-65.02, Technical Concept—Operation HENRE, F. F. Haywood and J. A. Auxier, 1965.
CEX-65.03, Operations Plan—Operation HENRE, Technical Director's Staff, 1965.
CEX-65.4, Biological Tolerance to Air Blast and Related Biomedical Criteria, C. S. White, I. Gerald Bowen, and D. R. Richmond, 1965.